

# Statistical and Semi-Dynamical Road Traffic Noise Models Comparison with Field Measurements

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**Abstract.** The need for road traffic noise monitoring is growing in urban areas due to the growth of vehicles number and to the consequent increase of risk for human health. Noise measurements cannot be performed everywhere, or even in a large number of sites, because of high costs and time consumption. For this reasons, Road Traffic Noise predictive Models (RTNMs) can be implemented to estimate the noise levels at any distance, knowing certain parameters needed as input of the RTNM. In this paper, the main statistical RTNMs are presented, together with the implementation of two innovative and advanced models: the EU suggested model (CNOSSOS-EU) and a research model presented by Quartieri et al. (2010). These models will be compared with noise measurements performed in different sites and with different traffic conditions, in order to avoid bias from geometry or other features of the area under study. The main conclusion is that the application of innovative models and the inclusion of dynamical information about traffic flow, will lead to better results with respect to statistical models.

## INTRODUCTION

The last years are characterized by a slow exit from the economic crisis, which had a relevant impact on the market of vehicles production and selling. In Western Europe (i.e. EU15 + EFTA countries), for instance, in the last four years new passenger cars registrations raised from 11.5 millions in 2013 to 14 millions in 2016, going back to the values observed before the crisis [1]. Of course, this increase of new vehicles in the road network can cause new environmental problems, in particular in terms of noise emissions. Even though new cars are strictly controlled and designed to be eco-friendly from the pollutant emissions point of view, their impact on soundscape cannot be completely neglected. In order to face this environmental issues, local and regional governments are generally required to monitor and periodically control noise in sensitive areas. In Europe, the Environmental Noise Directive 2002/49/EC [2] requires national government to implement several actions aimed at the long term monitoring of noise impact in urban areas. Of course, even if field measurements are usually more reliable than software predictions, it is very difficult to plan and implement a large scale measurement campaign. For this reason, Road Traffic Noise predictive Models (RTNMs) are usually implemented and adopted to create large areas noise maps and predictions. Several

models have been developed in literature, quite often adopting field measurements for the calibration of the parameters. In [3] and [4], the authors gave a detailed overview and presentation of several RTNMs. The EC suggests the CNOSSOS-EU model [5] to be the reference model for European countries. In [6], a comparison of some RTNMs predictions with field measurements observed in a single site in Italy is reported, while in [7] the standard models are resumed together with advanced procedures, based on innovative and advanced computing techniques, such as cellular automata [8], non-homogeneous Poisson processes [9]-[10], etc.. Dynamical approaches seem to be the most interesting direction, since, considering speed and acceleration, they can give a reliable description of real noise emission (see for instance [11], [12] and [13]). FEM/BEM approaches are also present in literature (see for instance [14] and [15]), for evaluating noise production and reduction. RTNMs can be also used for traffic management purposes and for multi-criteria approaches, as described for instance in [16], [17] and [18].

In this paper, a new comparison between some RTNMs results and field measurements is presented, in order to update this discussion to the latest models, developed on the basis of new computing techniques. The results will show that the statistical approach is almost overtaken, since the introduction of dynamical aspects of the traffic flow will generally bring to better results.

## PREDICTIVE MODELS DESCRIPTION

The need to predict road traffic noise rose many years ago. First attempts have been developed in the 1950s. A detailed description of the most used RTNMs is presented in [3] and [4].

In Figure 1 we report a plot of several models results as a function of the traffic volume, to show how different can be the predictions according to the chosen model. Since the Burgess model provides the lowest result among the fully statistical models, this one will be chosen for the comparison presented in this paper. Let us also underline that the semi-dynamical models, CNOSSOS and Quartieri et al. models, that in figure seem to produce results much lower than the others, are affected by the choice of the mean speed value. Modifying this parameter, a shift in the curves can be observed, upward or downward according respectively to an increment or a decrement of the mean speed of the flow.

In the following subsections, the basic formulas of the models that will be used in the comparison are briefly resumed.

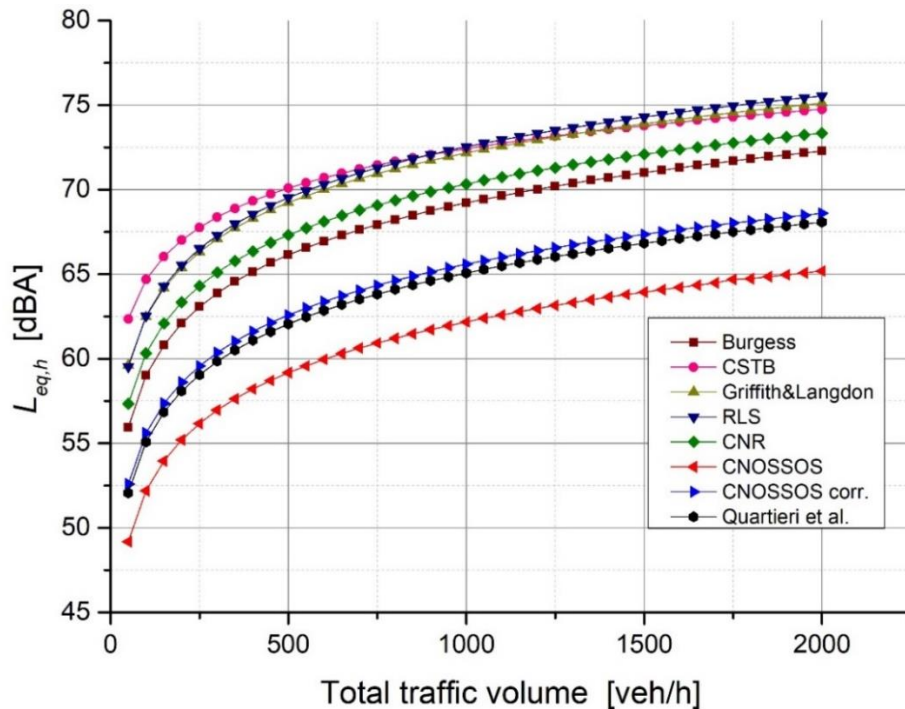


FIGURE 1. Traffic Noise Models predictions as a function of the traffic flow.

### Model 1: Burgess

Among the statistical models, the one implemented by Marion Burgess [19] is maybe the most famous. Its simplicity allows to produce a prediction knowing the hourly flow of vehicles ( $Q$ , in veh/h), the percentage of heavy vehicles ( $p$ ) and the distance ( $d$ , in meter) between the middle of the carriage and the receiver. The prediction is given in terms of the hourly equivalent level, according to the following formula:

$$L_{eq} = 55.5 + 10.2 \log Q + 0.3p - 19.3 \log d \quad \text{i)}$$

### Model 2: CNOSSOS-EU

The second model that will be implemented in the comparison is the one suggest by the EC as the reference model. It is called CNOSSOS-EU [5]. The general idea is to evaluate the source power level of the traffic, assumed to be a line source, composed by several point sources moving on the road, each of them including the rolling and the propulsion sources. Once the source power level of the flow is estimated, the propagation at the receiver is calculated, assuming certain percentages of “favorable” and “homogeneous” conditions and including possible reflections and diffractions. For the sake of brevity, the formulas for evaluation of the equivalent level produced by road traffic will be not reported in this paper, but can be found in [5]. Let us just underline that CNOSSOS introduced a mean speed of the traffic flow, as a clear attempt to dynamically approach the noise prediction, and that, when possible, some of the corrections will be implemented to improve the prediction.

### Model 3: Quartieri et al.

Two years before the publication of CNOSSOS guidelines, Quartieri et al. presented a simple way to modify the general statistical approach for road traffic noise prediction, including the mean speed as input parameter [20]. The SEL of the single vehicle is estimated with some assumptions and approximations (for a complete report, the reader may refer to [20]). Then, the hourly  $L_{eq}$  at a certain distance  $d$  from the center of the carriage is obtained summing on the vehicle index, including also heavy duty vehicles. A coefficient to take into account the different noise produced by heavy duty vehicles ( $N_H$ ) with respect to light duty vehicles ( $N_L$ ) is introduced and called “acoustic equivalent” ( $n$ ). The hourly equivalent level calculated with this model is obtained by:

$$L_{eq} = 10 \log(N_L + nN_H) + \alpha_L + \beta_L \log v - 20 \log d - 46.563 \quad \text{ii)}$$

where  $\alpha_L$  and  $\beta_L$  are coefficients obtained with an experimental fit (in this application  $\alpha_L = 53,6 \pm 0,3$  dBA and  $\beta_L = 26,8 \pm 0,2$  dBA).

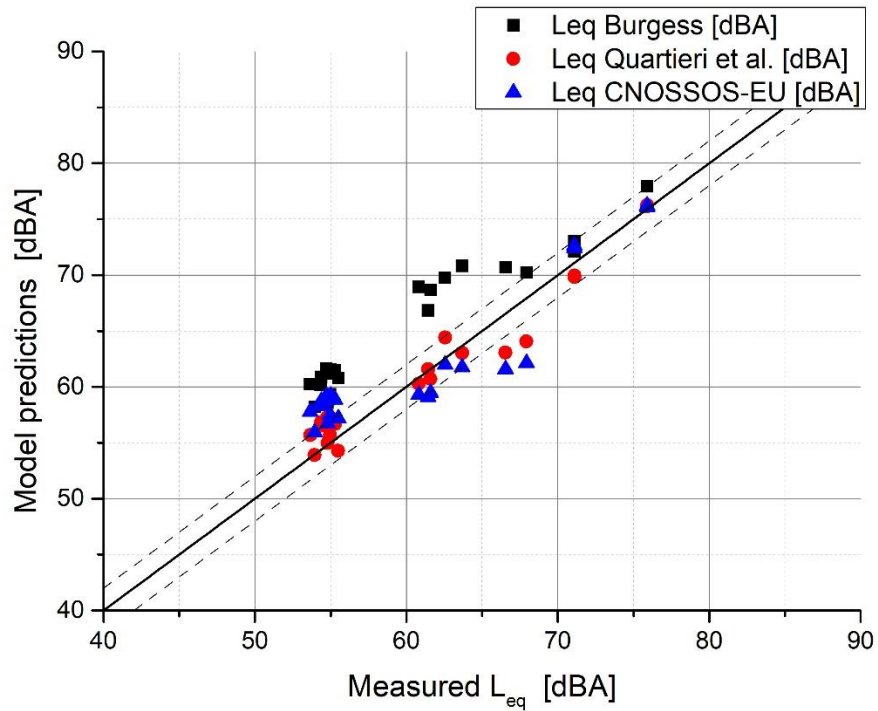
## COMPARISON WITH FIELD MEASUREMENTS

In order to perform the comparison with field measurements, 3 datasets have been merged, for a total of 25 measurements. The data have been collected in the framework of research activities carried out by the groups of the University of Aveiro and the University of Salerno. The measurements used for the comparison include both urban roads and highways locations, and have a certain variation in the site and geometry, the experimental equipment and the operators, that, of course, can affect the measurements. In particular, three sites are considered, one in Spain (Badajoz), one in Italy (Baronissi, Salerno) and one in Portugal (Guimaraes). It is interesting to notice that the sites differ in terms of range of hourly traffic volume, heavy duty vehicles percentages, geometry, mean speeds and range of equivalent levels. This will be helpful in order to see how the models perform in different conditions.

The details of the measurements used for the comparison are reported in Table 1, while in Figure 2 the RTNMs predictions obtained using the data of each measurement as input, are reported versus the field measurements themselves. This “bisector plot” gives an immediate idea of whether the results of RTNMs are close to observed data or not. If the points gather close to the bisector, it means that there is a good correspondence between the dataset and the measured levels.

**TABLE 1.** Resume of the measurements used in the comparison with RTNMs predictions.

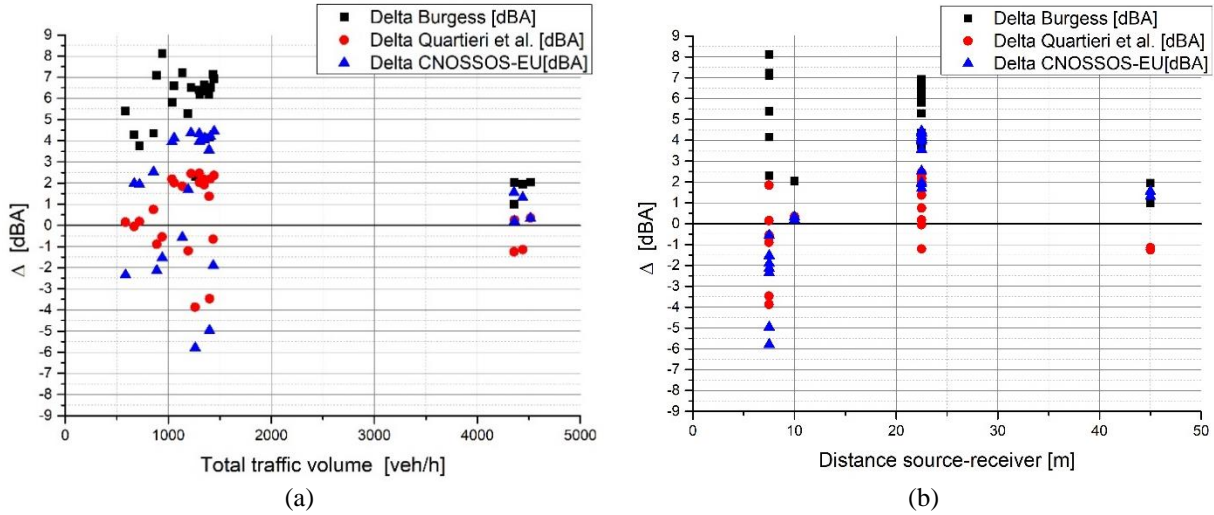
Measurement location and number	Range of hourly traffic volume [veh/h]	Range of heavy vehicles percentage	Range of mean speed of the flow [km/h]	Distance source-receiver [m]	Range of measured $L_{eq}$ [dBA]
Badajoz 14 measurements	668-1444	2%	40.6-52-1	22.5	53.7-55.5
Baronissi 4 measurements	4356-4516	14.9%-19.5%	75	10, 45	71.1-75.9
Guimaraes 7 measurements	584-1436	0.4%-1.6%	33.7-44.8	7.5	60.8-67.9

**FIGURE 2.** Comparison between model results and measured  $L_{eq}$ . Lines are the bisector (solid) and bisector  $\pm 2$  dBA (dashed)

Looking at Figure 2, we can distinguish three ranges of noise levels: below 60 dBA, that corresponds to the Badajoz measurements, between 60 and 70 dBA, related to Guimaraes, and over 70 dBA, i.e. measurements taken in Baronissi. In all the cases, the Burgess model gives an overestimation of the observed levels, reducing this discrepancy when the measured levels are over 70 dBA. The CNOSSOS model, on the other hand, overestimates in the low levels range, underestimates in the mid-range and gives very good results in the latter. The model developed by Quartieri et al. basically follows the CNOSSOS one, but with better results on average.

The difference (delta,  $\Delta$ ) between models results and observed noise levels can be easily evaluated in each measurement and can be used as a preliminary error indicator. The mean of the error for the Burgess model is 5.2 dBA, confirming the general overestimation observed in Figure 2. For the Quartieri et al. and CNOSSOS-EU models, the mean errors are respectively 0.5 dBA and 1.3 dBA. Even these values confirm the better performances of the semi-dynamical models with respect to the fully statistical one.

In Figure 3, the difference (delta,  $\Delta$ ) between models results and observed noise levels is plotted as a function of total traffic volume (Fig. 3(a), left) and distance source-receiver (Fig. 3(b), right). Besides the remarks about underestimation and overestimation of the models given above, it can be noticed that for low traffic volumes the spread of the delta of all the models is much greater than for high traffic volume. Similar behavior is observed with the distance: when it is under 10 m, the spread of the delta of all the models is much greater than at higher distances.



**FIGURE 3.** Difference (delta,  $\Delta$ ) between models results and observed noise levels as a function of (a) total traffic volume and (b) distance source-receiver

## CONCLUSIONS

In this paper, a preliminary comparison between Road Traffic Noise predictive Models (RTNMs) and noise level measurements is reported. The dataset used for the comparison is composed by measurements collected in three different locations and countries, with different conditions in terms of traffic volume, geometry, distance source-receiver, etc.. These different conditions led to three ranges of noise level values: low (between 50 dBA and 60 dBA), medium (between 60 dBA and 70 dBA) and high (above 70 dBA). In these intervals, the models exploited different behaviors, in terms of overestimation and underestimation. In general, the fully statistical model gave a general overestimation in all the sites. The semi-dynamical models, that adopted the mean speed of the flow as one of the input parameters, performed better than the other. This is the indication that a well implemented RTNM cannot neglect the dynamics of the flow, even only with the inclusion of the mean speed as input.

The analysis of the “Delta” ( $\Delta$ ), i.e. the difference between model prediction and observed noise level in each site and each measurement, showed that the better results are achieved by all RTNMs when the traffic volume and the distance source-receiver increase. On the contrary, the highest spread of delta values is obtained for low flows and short distances, when probably the approximations and neglects included in the models building fail.

The possible extension of this work is represented by the inclusion of more models (statistical, semi-dynamical and dynamical) and more experimental datasets (low and high noise levels cases and mid-range traffic volumes and distances data), in order to build a complete and up-to-date review of how RTNMs behave in different conditions.

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